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The Mountain Pine Beetle, an Important Enemy of Western Pines

By JAMES C. EVENDEN, *senior entomologist*, and W. D. BEDARD and G. R. STRUBLE, *associate entomologists, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration*

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INTRODUCTION

Each year the mountain pine beetle takes a toll of more than a million dollars' worth of commercially valuable pine from the forests of the Northwestern and Pacific Coast States. This drain upon the timber resources of the region is equal to a large percentage of the volume cut for lumber and is an important factor in the essential practice of sustained-yield forest management.

In addition to its monetary value, there are other factors of importance associated with this loss of timber. Trees killed by beetles stand as snags for years or lie as inflammable debris upon the forest floor, materially increasing the forest-fire hazard. Not only is annual growth offset by this loss, but in some forest types the destruc-

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tion of a large percentage of one tree species changes the composition of the stand so that a revision of management plans is often required.

During wartime, when such large quantities of lumber are needed for war construction and housing, it is especially important to make use of all practical methods of preventing the destruction of valuable pine timber. Control of this destructive bark beetle therefore becomes increasingly urgent.

This circular covers the variety of problems associated with the mountain pine beetle throughout its entire range, describes how it kills healthy mature trees, its habits, and the methods that are available to prevent and suppress destructive outbreaks.

IMPORTANCE IN FORESTRY

The mountain pine beetle (*Dendroctonus monticolae* Hopk.) is a serious enemy of pine forests in the Northwestern and Pacific Coast States. This bark beetle attacks a number of valuable species of pine in Idaho, Montana, northwestern Wyoming, Oregon, Washington, and California, and in the Canadian Province of British Columbia (fig. 1).

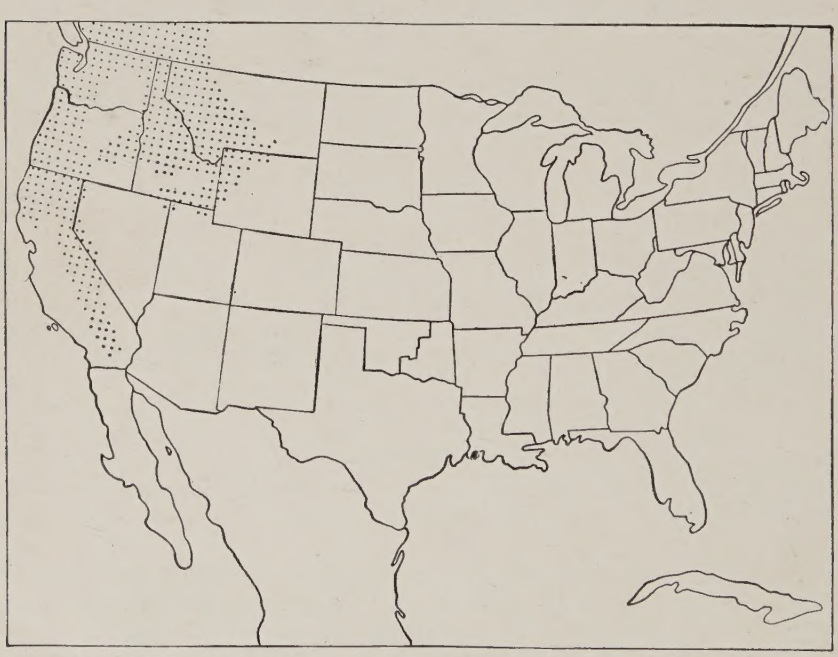

FIGURE 1.—Distribution of the mountain pine beetle, shown by dots on the map.

Epidemics of the mountain pine beetle have swept through thousands of acres of mature lodgepole pine in the northern Rocky Mountains, killing practically all trees larger than 8 inches in diameter. This beetle takes a heavy annual toll from the valuable white pine forests of northern Idaho and western Montana, where many stands

have been seriously depleted. In California and southern Oregon the highly prized sugar pines are periodically subjected to severe economic losses as a result of its attack.

The economic importance of this insect was first brought to the attention of forest-managing agencies in 1907, when a serious outbreak occurred within the lodgepole and ponderosa pine stands of the Whitman and Wallowa National Forests of northeastern Oregon. Control was directed against this outbreak in 1910, and since that time many projects have been conducted within the white pine, lodgepole pine, and sugar pine stands in the western part of the United States.

The importance of the mountain pine beetle as an enemy of forest trees can be illustrated by presenting a few examples of actual timber losses. From 1925 to 1935 approximately 38 percent of the mature lodgepole pines of Idaho and Montana, or more than 7 billion board feet, was destroyed by this insect. From 1930 to 1939 the annual loss of merchantable white pine as a result of mountain pine beetle activity in Idaho and Montana amounted to 91 million board feet.

In Oregon and Washington this beetle has killed large volumes of lodgepole pine and white pine along the higher elevations of the Cascade and Blue Mountains. Such losses have been of special concern in national parks and recreational areas. Occasionally it has been a serious menace to young pole stands of ponderosa pine, especially on cut-over areas and in places where such stands are suffering from severe competition. Older ponderosa pines are not so susceptible to its attacks.

In California, sugar pines containing between 70 and 100 million board feet were killed annually from 1920 to 1940. Periodically this loss is increased manyfold by epidemic infestations of this destructive beetle. For example, from 1931 to 1933 the total loss rose to 690 million board feet annually.

The mountain pine beetle does not confine its activity to commercial forests; many pine stands valuable from an aesthetic or protection standpoint have been practically destroyed by its activity. There is no way of estimating the real monetary value of such forests, but there is no doubt that it often exceeds that of commercial timber.

Insect-killed trees play an important part in programs of fire prevention and suppression. Epidemics of the mountain pine beetle in lodgepole pine leave forests of dead trees that become impenetrable tangles of fallen snags and constitute a serious fire menace for several decades. When fires start in such masses of inflammable material, widespread conflagrations occur that are most difficult to suppress. Snags of insect-killed white pine, sugar pine, and ponderosa pine add to the cost, danger, and difficulty of fire suppression (figs. 2 and 3).

The successful management of white pine forests requires consideration of the important role played by the mountain pine beetle. As insect-killed white pine trees are seldom replaced by the same species, this change in timber type leaves a forest of different composition, usually of an inferior species, requiring a reorganization of management plans. This is also true in those lodgepole pine stands where shade-tolerant species occur as an understory and where conversion to a climax type is hastened by removal of the lodgepole pine.

FIGURE 2.—A white pine stand in which the snags resulting from insect-killed trees have been felled.

FIGURE 3.—Group of bleached sugar pine snags. Within 5 or 6 years after they are killed by the mountain pine beetle, sugar pines take on this ghost-tree appearance.

THE BEETLE

The mountain pine beetle (fig. 4, *D*) was described by Hopkins[1] in 1909. It is a stout, black, cylindrical beetle approximately one-fourth of an inch long. During its development it passes through successive stages of egg, larva, pupa, and adult. Immature beetles are yellowish to brown, but mature beetles are jet black. The eggs (fig. 4, *A*) are small and oval and approximately one-thirtieth of an inch in diameter. The larvae (fig. 4, *B*) are white, legless grubs with brown heads, and when mature they are of the same size as the beetles. Pupae (fig. 4, *C*) are also white and are in the transitional stage from larvae to adults. The external characters of the adults can be seen on the pupae.

[1] HOPKINS, A. D. THE GENUS DENDROCTONUS. U. S. Dept. Agr. Bur. Ent. Tech. Ser. 17, Pt. 1, 164 pp., illus. 1909.

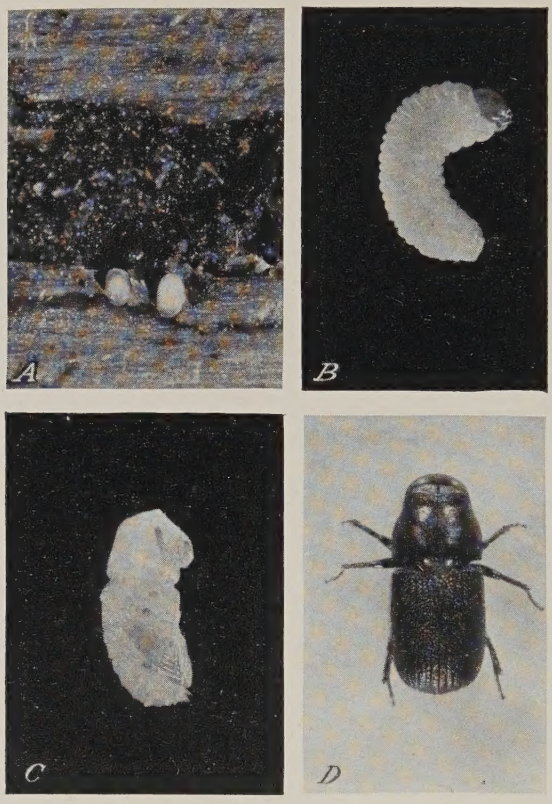

FIGURE 4.—The mountain pine beetle: *A*, Eggs; *B*, larva; *C*, pupa; and *D*, adult. Each five times natural size.

WORK AND HABITS

HOST TREES

The mountain pine beetle attacks many species of pine that occur throughout its range. These include western white pine (*Pinus monticola* D. Don.), lodgepole pine (*P. contorta latifolia* Engelm.), sugar pine (*P. lambertiana* Dougl.), ponderosa pine (*P. ponderosa* Lawson), whitebark pine (*P. albicaulis* Engelm.), limber pine (*P. flexilis* James), and sometimes Engelmann spruce (*Picea engelmannii* Engelm.) when occurring in areas of infested white pine. Because of widely varying climatic conditions throughout the range of its different hosts, this insect has adapted its habits and life cycle to satisfy its requirements under each environmental variation encountered.

Under the conditions of each forest environment the mountain pine beetle makes a definite selection of tree species. In the western white pine type forests of northern Idaho and western Montana it prefers white pine. Whitebark pine or limber pine occurring in association with or adjacent to areas of lodgepole pine is attacked in preference to the latter, although, as previously stated, severe epidemics occur in lodgepole pine. In California the beetle selects sugar pine in preference to ponderosa pine.

During endemic, or normal, infestations this bark beetle prefers overmature or weakened trees, windfalls, and cull logs from thick-barked tree species. Abnormal quantities of windfalls or cull logs provide favorable breeding places for large numbers of the beetle. The unusually large broods of beetles that emerge from this material spread to adjacent areas and cause severe damage to both young and mature timber stands. The source of heavy localized infestation in sugar pine and white pine has been traced to abnormal supplies of such host material.

Frequently the mountain pine beetle will attack tree species that are not normally attractive to it. For example, Engelmann spruce is attacked when it occurs in association with or adjacent to an infested area of white pine. White fir (*Abies grandis* Lindl.) and incense-cedar (*Libocedrus decurrens* Torrey) mixed with sugar pine are sometimes attacked, but no broods are developed. These so-called "freak attacks" are of no importance, and their cause is ascribed to an overflow of beetles from preferred host trees nearby.

Recognition of Attacks

Basal attacks of the mountain pine beetle, typical on such thin-barked trees as lodgepole pine, white pine, and young sugar pine, can be recognized by the reddish-brown pitch tubes (fig. 5) which form at

Figure 5.—Pitch tubes on lodgepole pine attacked by the mountain pine beetle. Natural size.

the mouth of the entrance hole made by each attacking beetle, and by the boring dust (fig. 6) around the base of the tree or caught in bark crevices on the bole. The size of the pitch tubes is determined by the amount of resin issuing from the wound, which is often so great that the attacking beetles are drowned out. These are called pitched-out attacks. The absence of pitch tubes indicates that the resin flow was insufficient to cause their formation.

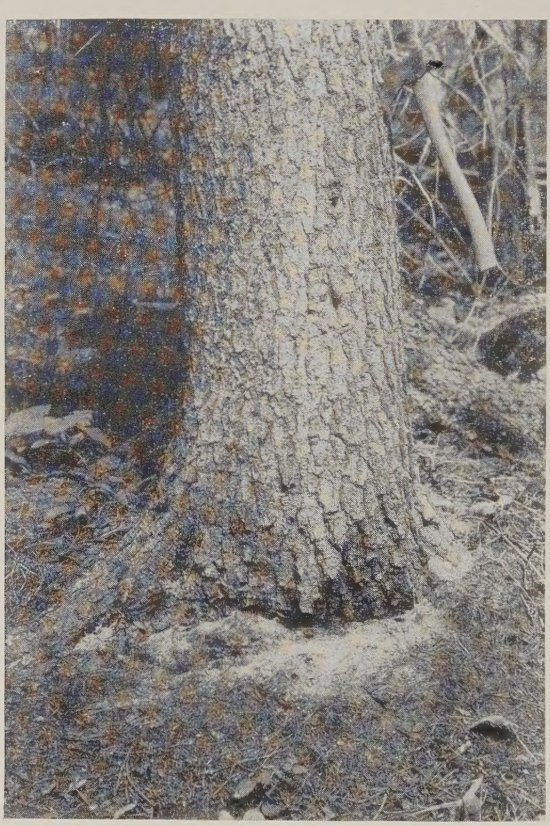

FIGURE 6.—Boring dust at the base of a lodgepole pine tree, indicating attack by the mountain pine beetle.

Mature sugar pine trees are killed usually by successive mountain pine beetle attacks which begin at the top (figs. 7, 8, and 9) and extend downward. This characteristic prevents the recognition of attack until the foliage of the infested portion of the bole has begun to fade. After the upper bole is attacked, the red turpentine beetle (*Dendroctonus valens* Lec.) infests the base, indicating a rapid weakening of the entire tree. The large pitch tubes associated with the attacks of the red turpentine beetle are easily recognized.

A successful beetle attack results in the death of the infested tree, although there is marked variation in the time between the initial attack and the first evidence of foliage discoloration. On some trees

the foliage fades after a lapse of 3 or 4 weeks, while on others, even of the same species, there is no discoloration for several months after attack. Trees attacked on only one side will remain green as long as the crown obtains sufficient moisture through the unattacked side. Eventually the foliage of all successfully attacked trees fades through successive stages of yellow, sorrel, and red, and then falls from the trees. Spruce trees provide an exception, for, although there is some slight fading, the needles fall a few weeks after attack while still light green.

When a piece of bark is removed from an infested tree, the work of the mountain pine beetle is shown on its inner side as well as on the

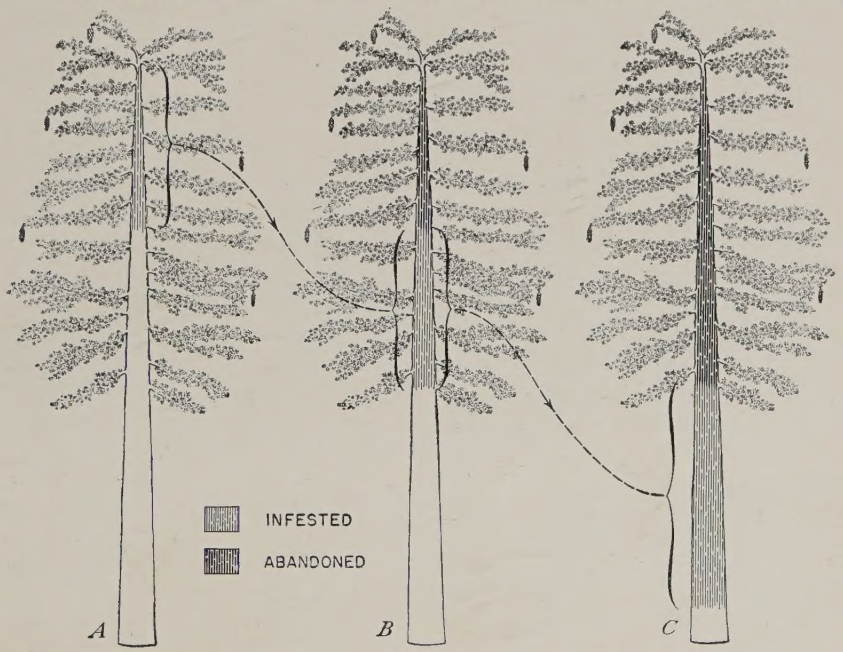

FIGURE 7.—How the mountain pine beetle kills mature sugar pine. Three successive generations may develop in the same tree as the attack progresses from the top to the base. This progressive attack may extend through two seasons before a tree has been infested completely.

A, Initial attack in the upper crown. The beetles attack, extend egg galleries, develop broods, and emerge.

B, Attack in the midbole. Beetles emerging from the infested area above or from other trees attack here.

C, Attack on the lower bole. This completes the killing. This attack may not occur until the second season after the initial attack on the crown. The lower part (5 to 10 feet at base) is usually attacked by *Dendroctonus valens*.

wood surface (fig. 10). This work pattern is composed of egg galleries made by parent beetles, larval mines made by developing larvae, and pupal cells made by the larvae prior to their transformation to pupae. The egg gallery, which is always packed solidly with boring dust, is about $\frac{3}{16}$ inch in width and from 3 to 24 inches or more in length. It extends upward following the grain of the wood, with a sudden offset

or crook at the bottom. Eggs (fig. 4, *A*) are deposited singly in small niches along the sides of the egg gallery, and the larvae that hatch from them excavate feeding tunnels at approximately right angles to the parent gallery (fig. 11), forming a pattern peculiar to this insect.[2] There are some variations from this general gallery pattern, for in sugar pine (fig. 12) it is not unusual for the egg gallery to wind aimlessly in a pattern resembling that made by the western pine beetle (*Dendroctonus brevicomis* Lec.). After the larvae have reached maturity they excavate shallow oval pits, known as pupal cells, in which they transform to the pupal and then to the adult stage. In thin-barked trees these cells are between the bark and wood, but in large sugar or ponderosa pine trees having thick bark some of the cells may be within the inner bark. New adult beetles are white at first, darkening gradually as the body walls harden, until the black of the

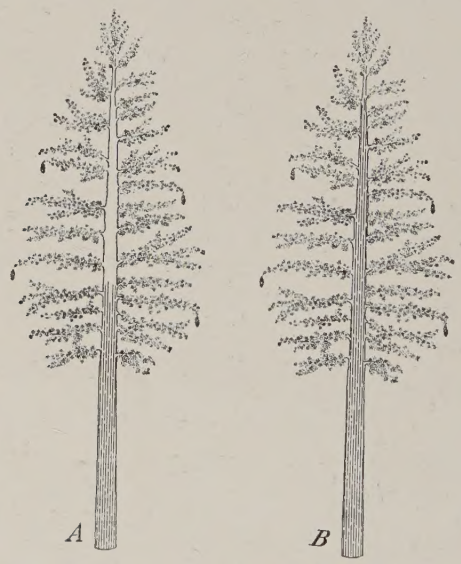

FIGURE 8.—How the mountain pine beetle kills thrifty young to mature sugar pine. Younger trees are killed by the attack of one generation.

A, Attack starts at the base and extends up to the middle. This type is comparable to the attack habit of this beetle on lodgepole pine.

B, Attack extends from the base to the thin bark of the upper crown. This type occurs in middle-aged trees.

mature adults is reached. Several weeks are required for this transformation, after which the new adult beetles may bore away the bark between pupal cells and congregate in the larger cavities. When their development is complete, the beetles bore through the bark and fly to trees selected for attack. Where several young adults occur in a group, one exit hole may serve for the emergence of all.

[2] A gallery very similar to that made by the mountain pine beetle is made by the Black Hills beetle (*Dendroctonus ponderosae*), an insect which is found in the southern Rocky Mountain region.

FIGURE 9.—Fading foliage in the top of a large sugar pine tree, indicating a mountain pine beetle infestation in the upper third of the bole. Three months after this photograph was taken another section of the crown immediately below was attacked.

Methods of Attack

Attacks are initiated by female beetles, which bore through the bark and excavate the egg galleries beneath. During the construction of the entrance holes, male beetles are attracted to the trees and follow the females as the tunnels progress. As pitch flows from wounded living tissue of the tree, the male keeps the entrance hole free of this resin and the boring frass, thus forming the pitch tube on the bark surface. Fertilization occurs after the heavy flow of pitch has stopped, which is usually when 1 or 2 inches of egg gallery have been excavated. After mating, the males may leave the tree, possibly

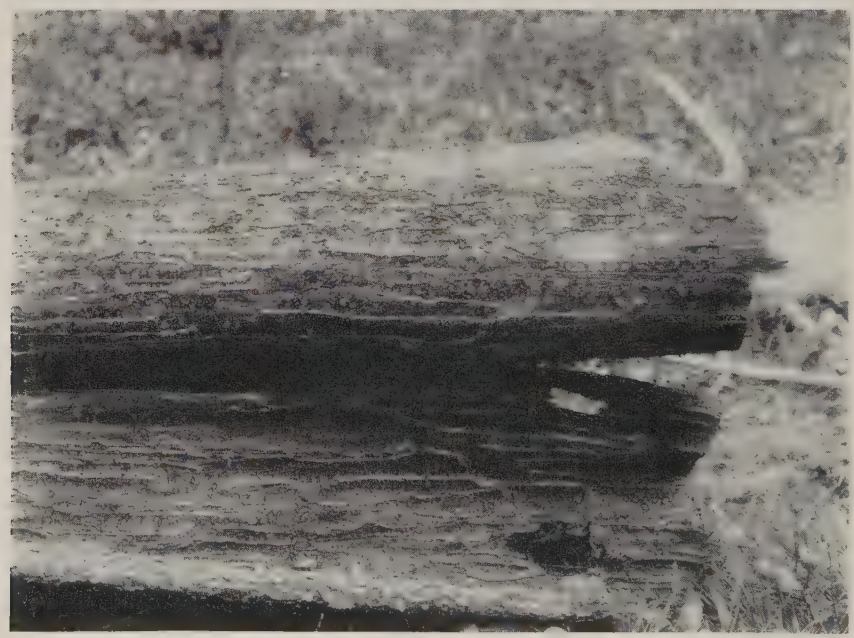

Figure 10.—Gallery pattern of the mountain pine beetle exposed by removing the bark from an infested lodgepole pine tree.

to seek new mates. If they remain, they are obliged to pack the frass into the tunnel as it is made by the female, to avoid being surrounded by it. Males suffer a greater mortality than females, as they remain on the bark surface for longer periods and are thus exposed to predators for a longer time. Of those that remain in the egg galleries, a number become imbedded in pitch and frass.

After completing an egg gallery, some parent beetles emerge and make a second attack by entering another green tree or uninfested portions of a lightly attacked tree. During unusually long seasons individual female beetles may make three separate attacks. The extent to which this habit occurs varies considerably among different host trees. For example, only 10 to 30 percent of the parent adults emerge from infested sugar pine, while from western white pine

nearly all of them emerge and reattack. Owing to the greater mortality of male beetles and the habit of emerged parent adults of joining with new beetles in attacking new trees, more females than males are found in nearly all instances.

FIGURE 11.—Pupae and young adults of the mountain pine beetle lying in cells constructed by the larvae in the inner bark.

FIGURE 12.—Winding egg galleries of the mountain pine beetle in sugar pine.

TYPES OF INFESTATION

Infestations of the mountain pine beetle are classed as epidemic outbreaks or as being in an endemic, or normal, status. During normal infestations the attacks of this beetle are confined mostly to the less vigorous trees of an area. Although the losses resulting from such infestations are not spectacular and are scattered throughout large areas, they often prove to be far more serious than anticipated and more or less offset the increment resulting from annual growth. This is especially true in mature sugar pine and western white pine, where over a period of years the destruction of timber from these so-called normal infestations often results in a serious depletion of the potential volume.

At irregular intervals, under conditions favorable to an increase in its numbers, the mountain pine beetle causes widespread and excessive timber loss (figs. 13 and 14). Such outbreaks are termed epidemic

FIGURE 13.—Epidemic infestation of the mountain pine beetle in white pine. Discolored foliage of insect-killed trees shows white in the photograph.

FIGURE 14.—Widespread mountain pine beetle infestation in lodgepole pine. Discolored foliage of killed trees shows white in the photograph.

infestations, and their seriousness depends upon their duration, the volume and character of timber destroyed, and the threat to adjacent timber stands.

Spread of Infestations

Records show that infestations of the mountain pine beetle have crossed timberless areas from 15 to 20 miles in width. This fact indicates that these beetles are able to make long flights or can be carried by air currents, with perhaps both factors playing an important part in such dissemination. Although such flights occur, there is no conclusive evidence as to the distance or direction these insects will move. The local spread of an infestation is no doubt governed by the availability of host material. The direction of widespread dissemination beyond the limits of local attraction must be one of chance, determined largely by air currents. However, the direction of such air currents is too uncertain to permit them to be of much use in predicting the direction of bark beetle flight. Directionless flights must result in many beetles being carried into timberless or non-host-tree areas where they subsequently perish.

Seasonal History

The seasonal history of the mountain pine beetle [3] varies with localities and elevations and is somewhat complicated, as shown by the relatively long period during which attacks occur in some regions and the overlapping in brood stages caused by individual variations in the rate of development.

In northern Idaho, western Montana, and Washington there are three periods of attack, the first throughout June, the second from the middle of July to the middle of August, and the third, which in reality is the tapering off of the second, from the middle of August to the end of the season. Broods generated during the first attack period attain the adult stage by September, and although there may be some emergence during the fall, a complete emergence does not occur except during seasons of protracted warm weather. Under such conditions a partial second generation occurs in this region. Broods from the second attack period overwinter as mature larvae, which pupate the following June, and reach the adult stage, emerge, and attack during July. The broods generated by the late attacks overwinter as tiny larvae, which do not attain the adult stage until the following August and September, when they emerge and attack.

In eastern Montana and central Idaho the developmental season is shorter, owing to the higher elevation of that region. There the beetles make their first attacks in July, attain maximum abundance during August, and then gradually diminish in numbers until the end of the season. Broods generated by these attacks emerge approximately 1 year later, so there is but one generation a year. At extremely high elevations the seasonal development is even more retarded, and as long as 2 years may be required for the development of a single generation.

[3] DeLeon, D., Bedard, W. D., and Terrell, T. T. Recent discoveries concerning the biology of the mountain pine beetle and their effect on control in western white pine stands. Jour. Forestry 32: 430–436, illus. 1934.

In southern Oregon and California there are two complete generations annually, and a partial third in years when activity begins unusually early in the spring. The flight of adult beetles developed from overwintered larvae begins early in June and lasts until the middle of July, when attacks are made which produce the summer generation. The new adults of the summer generation begin emergence late in August and continue through September and early October. These beetles attack trees and produce broods which develop to large larvae, pupae, and new adults by the time winter temperatures cause hibernation. Attacks initiated in March, April, or May by overwintering adults result frequently in the production of two complete summer generations and the beginning of a third. Adults from the first of these generations emerge early in July; those from the second generation emerge during September to establish a third generation, which overwinters in the larval stage.

NATURAL CONTROL

Populations of the mountain pine beetle are influenced both directly and indirectly by a number of natural factors which tend to hold infestations of this insect in check. These may be grouped under environmental resistance, which includes climatic influences as well as the biological agents which prey directly upon the beetle.

Beneficial effects of weather may be realized in bark beetle mortality resulting from unseasonably low temperatures before the insects have developed sufficient resistance to withstand such conditions, or the action may be indirect, as influencing the vigor of the host plant.

Although beneficial weather conditions play an important part in governing bark beetle populations, they are not dependable; so any attempt to utilize natural factors in the control of the mountain pine beetle must rest with biological agents. Even in this broad classification the inconsistency of favorable action from such factors as birds and mammals makes a planned use of their activity impossible. Likewise it is obvious that insect diseases, which are so dependent upon proper conditions of temperature and moisture, can be recognized only as a factor which may aid in artificial control.

A number of insects, both parasitic and predaceous, prey upon the mountain pine beetle.[4] The more important of these are the braconid *Coeloides dendroctoni* Cush.; two pteromalids, *Cecidostiba dendroctoni* Ashm. and *Pachyceras eccoptogastri* Ratz.; two flies, *Medetera aldrichii* Wheeler, a dolichopodid, and *Lonchaea viridana* Meig., belonging to the family Lonchaeidae; and three beetles, *Enoclerus sphegeus* (F.) and *Thanasimus dubius* (F.), both clerids, and *Temnochila virescens* var. *chlorodia* (Mann.), an ostomatid. The first three listed are ectoparasitic upon the larvae; the larvae of the two flies are predaceous, feeding on all developmental stages of the mountain pine beetle beneath the bark; while the three beetles are predaceous in both the adult and larval stages, the adults feeding on mountain pine beetle adults as they leave or attack the tree, and the larvae feeding on all developmental stages beneath the bark.

[4] DeLeon, D. AN ANNOTATED LIST OF THE PARASITES, PREDATORS, AND OTHER ASSOCIATED FAUNA OF THE MOUNTAIN PINE BEETLE IN WESTERN WHITE PINE AND LODGEPOLE PINE. Canad. Ent. 66 (3): 51–61. 1934.

The activity of the parasitic insects is limited by bark thickness, as they are unable to oviposit through bark more than one-half inch thick. The larvae of predaceous beetles and flies, however, are of considerable importance beneath the thick bark of beetle-infested trees. As these beneficial insects are an important factor in reducing bark beetle populations, means are constantly being sought, in the administration of artificial control, to foster their development and preservation.

DIRECT CONTROL

In considering the possibilities of artificial control of bark beetles it must be recognized that the death of successfully attacked trees cannot be prevented. Control measures are directed toward the destruction of the insect broods beneath the bark to prevent their subsequent emergence and attack of other trees. Control projects are concerned with the reduction of existing infestations which constitute an immediate danger to valuable timber stands. In the administration of forest lands, bark beetle surveys, which vary for different timber types and regions and are vital to the success of all control projects, should be employed to reveal the status of existing infestations in different forest areas. In determining the seriousness of each specific situation, thought must be given to the possible development of epidemics that may subsequently spread into adjacent uninfested forested areas. Abnormal supplies of attractive host material, of which windthrows are of the greatest importance, are potential sources of destructive mountain pine beetle outbreaks. Such accumulations must receive the necessary attention to prevent the development of the abnormally large broods which occur in such material.

Although the immediate returns to be gained from artificial control are measured in the direct commercial value of the timber protected from attacks of these insects, there are other less tangible benefits to be derived. The importance of green forests to game and watershed protection, the prevention of dangerous fire conditions resulting from large numbers of insect-killed trees, and the value of forests as a means of preventing soil erosion, with, of course, the scenic values associated with them, are all examples of the intangible but important benefits associated with this phase of forest protection. With some forest types in specific areas, the value of these less tangible benefits often outweighs their commercial worth, and in all instances they play an important role in the management of forest lands.

When serious infestations are recorded by surveys, and associated forest conditions justify the institution of control, the actual treating of infested trees is in most cases preceded by a thorough survey (spotting) of the infestation unit, during which all infested trees are marked and their locations recorded on a map. Successful control operations should include all infested trees on an area of sufficient size or so bounded by natural barriers as to eliminate the possibility of reinfestation from adjacent untreated areas.

There are a number of methods of artificial control, adapted to different hosts and localities, that are used successfully against outbreaks of the mountain pine beetle. The method to be employed for each situation is determined quite largely by bark thickness and the size of the trees to be treated. For instance, the relatively small

diameters and thin bark of lodgepole pine make possible the use of methods of treatment which could not be used effectively with large, thick-barked trees.

Peeling

Removing the bark from the bole of infested trees was the first method of control used in suppressing bark-beetle epidemics within the United States. This method is still in general use and is employed in treating white pine and lodgepole pine trees when the use of fire becomes dangerous. The bark is removed with axes or with peeling spuds (fig. 15) that are adapted to different host trees. When exposed

Figure 15.—Peeling bark from infested white pine trees with "spuds."

the immature stages of the mountain pine beetle are quite promptly destroyed by predaceous insects, birds, and small mammals. This method of treatment is not considered effective against broods of new adults, although some mortality is obtained. A primary benefit resulting from this method of control is that it permits the peeled logs to be salvaged.

Peeling and Burning

The peeling-and-burning method is applicable to large, thick-barked sugar pines and ponderosa pines and can be practiced when conditions are favorable for burning. Infested trees are felled, and the bark is peeled (fig. 16) from the main trunk and larger branches.

Branches and bark are piled along both sides of the bole, and after a proper fire line has been constructed the material is burned. During unusually dry weather deep pits are excavated, in which the infested bark can be burned without danger.

FIGURE 16.—Preparing a large infested sugar pine tree for treatment. Limbs and bark are removed and piled along both sides of the trunk, and after a proper fire line has been constructed the debris is burned. (Courtesy of the National Park Service.)

FIGURE 17.—Decking and burning white pine trees infested with the mountain pine beetle. In steep terrain the logs are decked by hand.

Decking and Burning

When forest conditions permit, infested trees are felled, cut into convenient lengths, decked, and burned. In treating scattered infestations of small trees the logs are usually "hand-logged" into decks; when large groups occur, however, horses (fig. 17) or tractors can be used to advantage in skidding and decking.

When the decks are properly built, with the bottom logs on the ground and with no ends protruding, good burns are obtained by starting fires on the lower side. **Care must always be exercised with the use of fire, and when any danger exists all decks must be properly trenched and the fire kept under close observation.**

Burning Standing Trees

Infested lodgepole pine trees may be treated while standing by spraying a fuel oil upon the bole for immediate burning. The oil is applied from a portable pressure tank, and with the use of extensions the lower 25 to 30 feet of the bole can be covered. When all sides have been properly sprayed, a lighted match is thrown at the base and the fire is carried upward with additional oil. When the flames reach the upper limits of the sprayed portion of the bole, a hot fire is developed at this point by additional fuel, which in most instances will result in the flames burning upward through the crown (fig. 18). When the infested length of a standing tree cannot be properly treated in this manner, the tree must be felled and the bole sprayed with oil for burning. In some areas this modification has been adopted as a standard practice, and all trees are felled for such treatment. The burning-standing method of control is peculiarly adapted to lodgepole pine, because of its thin bark and relatively short infested length.

Using Penetrating Sprays

Sprays have been developed that penetrate the bark of infested lodgepole pine trees and destroy overwintered broods of the mountain pine beetle beneath. These sprays can be applied in the same manner as the fuel oils used in the burning-standing method of control, or the trees can be felled for treatment (fig. 19). In the application of this spray care must be exercised that the entire bark surface is properly covered. This method eliminates the objectionable use of fire, and also permits the execution of control during June and July when favorable working conditions prevail. On the other hand, there is an additional cost of spray materials, and more time is required in the treatment of each tree. The spray that has given satisfactory results is composed of four parts of Diesel oil and one part of orthodichlorobenzene.

Orthodichlorobenzene should not be used near a well or other exposed source of drinking water because, once the chemical reaches it, the water will absorb the odor and may be rendered unfit for use for a long time. When handling orthodichlorobenzene it is advisable to provide free circulation of air, since the vapor, when confined, acts as an anaesthetic and is irritating to membranes of the nose and

eyes. Actual contact of the chemical with sensitive tissues is not permanently harmful but may be extremely painful.[5] Hands should be protected with rubberized gloves.

FIGURE 18.—Burning standing lodgepole pine trees infested with the mountain pine beetle. (Courtesy of the National Park Service.)

TAKING ADVANTAGE OF SOLAR HEAT

When infested lodgepole pine trees are felled and exposed to the direct rays of the sun during periods when air temperatures of 80° to 90° F. prevail, the temperature beneath the bark will increase to a point that is lethal to all insect life.[6] A few days after the logs are felled they must be turned so that the under side will be exposed. Large logs must be turned three times. Although in open lodgepole

[5] To treat the eyes, bathe them with boric acid; to relieve a mild skin irritation, apply bicarbonate of soda.

[6] PATTERSON, J. E. CONTROL OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE BY THE USE OF SOLAR HEAT. U. S. Dept. Agr. Tech. Bul. 195, 20 pp., illus. 1930.

pine stands this method offers an effective and economical means of control, its use is limited to regions where clear skies and the proper air temperatures are the rule rather than an exception. Its use is not considered feasible in the higher elevations of the Rocky Mountains, but it is generally satisfactory south of latitude 45°.

FIGURE 19.—Spraying an infested pine tree with a penetrating spray. (Courtesy of the National Park Service.)

MECHANICAL PROTECTION

The use of repellent sprays as a means of protecting trees of high aesthetic value from mountain pine beetle attacks has not been successful. Although these experiments have for the most part been confined to lodgepole pine, there is little reason to assume that more favorable results would have been obtained on other host trees.

Lodgepole pine trees have been protected from attack by the mountain pine beetle by placing a 16-mesh wire screen envelope (fig. 20) around the lower 15 to 20 feet of the bole. As the first attacks of this insect occur in the lower portion of the bole, such screening apparently affords protection to the entire tree.

COST AND EFFECTIVENESS OF CONTROL

The cost of artificial control varies with the method used and the host to which it is applied. It also varies with the character of labor

employed, the wages paid, the intensity of infestation, and the efficiency of project administration. In view of these variables the clearest basis which can be offered as to the cost of treatment for different situations is the comparative output per effective man-day. This information, which is drawn from average conditions, follows.

Host:	*Control method and output*
White pine	Peeling, decking, and burning, 2 to 2½ trees.
Sugar pine	Peeling and burning, 1 tree.
Ponderosa pine	Peeling and burning, 1 to 2 trees.
Lodgepole pine	Peeling, 3 to 5 trees; using solar heat, 10 to 12 trees; decking and burning, burning standing, and applying penetrating sprays, 5 to 8 trees.

FIGURE 20.—Lodgepole pine tree protected from mountain pine beetle attack by screen barrier.

The success of mountain pine beetle control cannot be judged from the subsequent infestation that occurs upon a treated area. The normal increase or decrease of the beetle population being treated, the possibility of reinfestation from untreated timber stands adjacent, and the thoroughness of project execution all play an important part in determining the visual results of control. Although by destroying the brood within an infested tree its emergence and subsequent attack of other trees is prevented, the actual benefits derived from control vary with the relative values of these factors.

If all infested trees within an area were treated and no reinfestation occurred from outside sources, the beetle population would be elimi-

nated from the area, but if infested trees or portions of the unit were left untreated, the actual benefits of control would not be so evident. In explanation, if an insect outbreak were building at a ratio of 1 : 3, then for each tree treated three trees would be saved from attack the following season. On the other hand, if one tree were left untreated, three trees would be subsequently destroyed. However, if this ratio were reversed, it would be necessary to treat three trees to save one, and only one tree would be attacked for each three trees left untreated.

In evaluating the success of artificial bark beetle control upon a specific area, one must consider the potentials of the infestation on all adjacent areas which have contributed and will continue to contribute to the status of conditions within the treated area. The effectiveness of the control work is dependent upon the extent to which this source of reinfestation is eliminated or reduced. It can therefore be assumed that the infestation which follows the institution of control will be reduced in close proportion to the percentage of the contributing insect population destroyed.

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